



# AUTONOMOUS MOBILITY APPLIQUÉ SYSTEM (AMAS)

Robotics cooperation workshop  
(May 24-26, 2011)

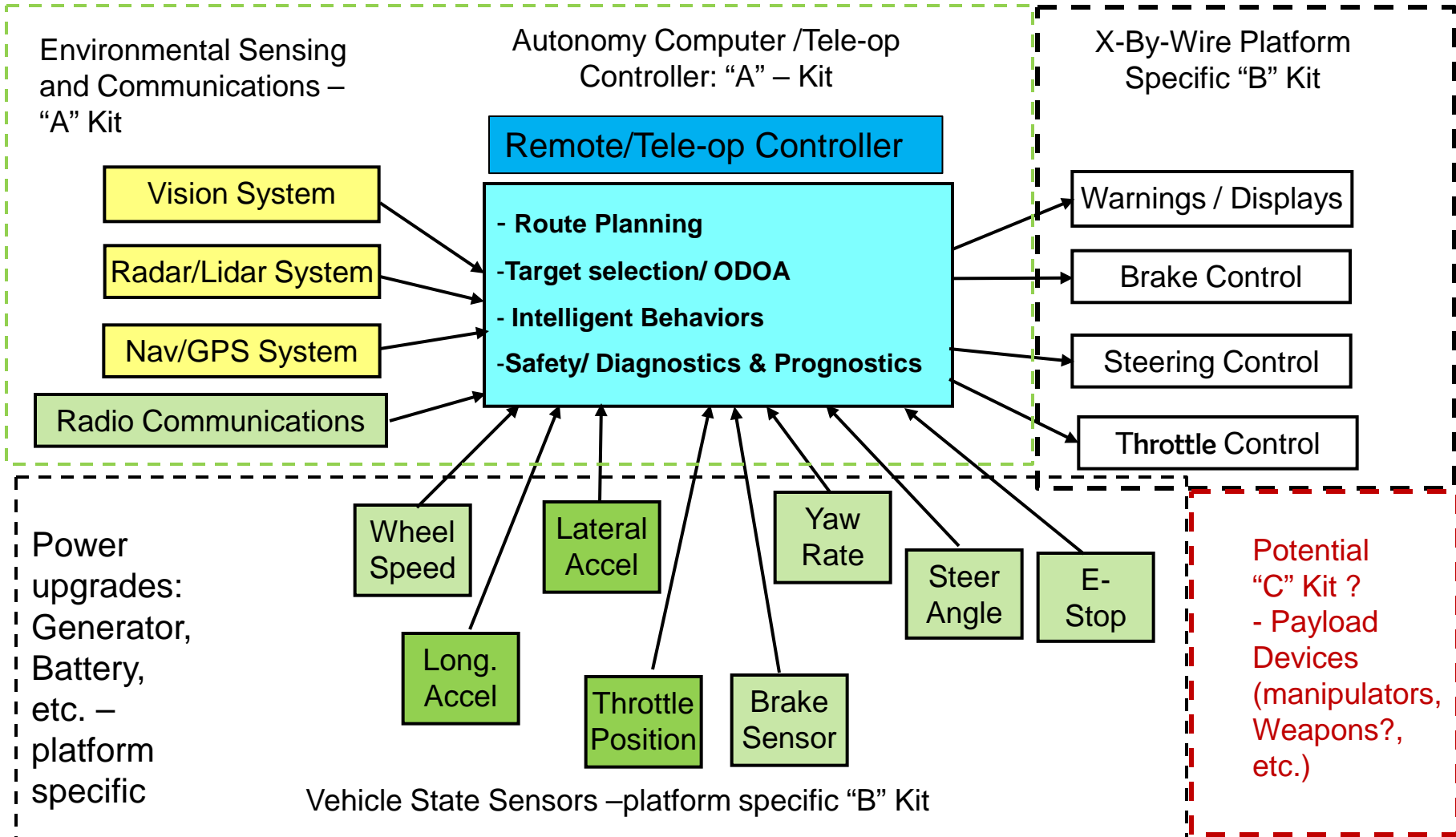


**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

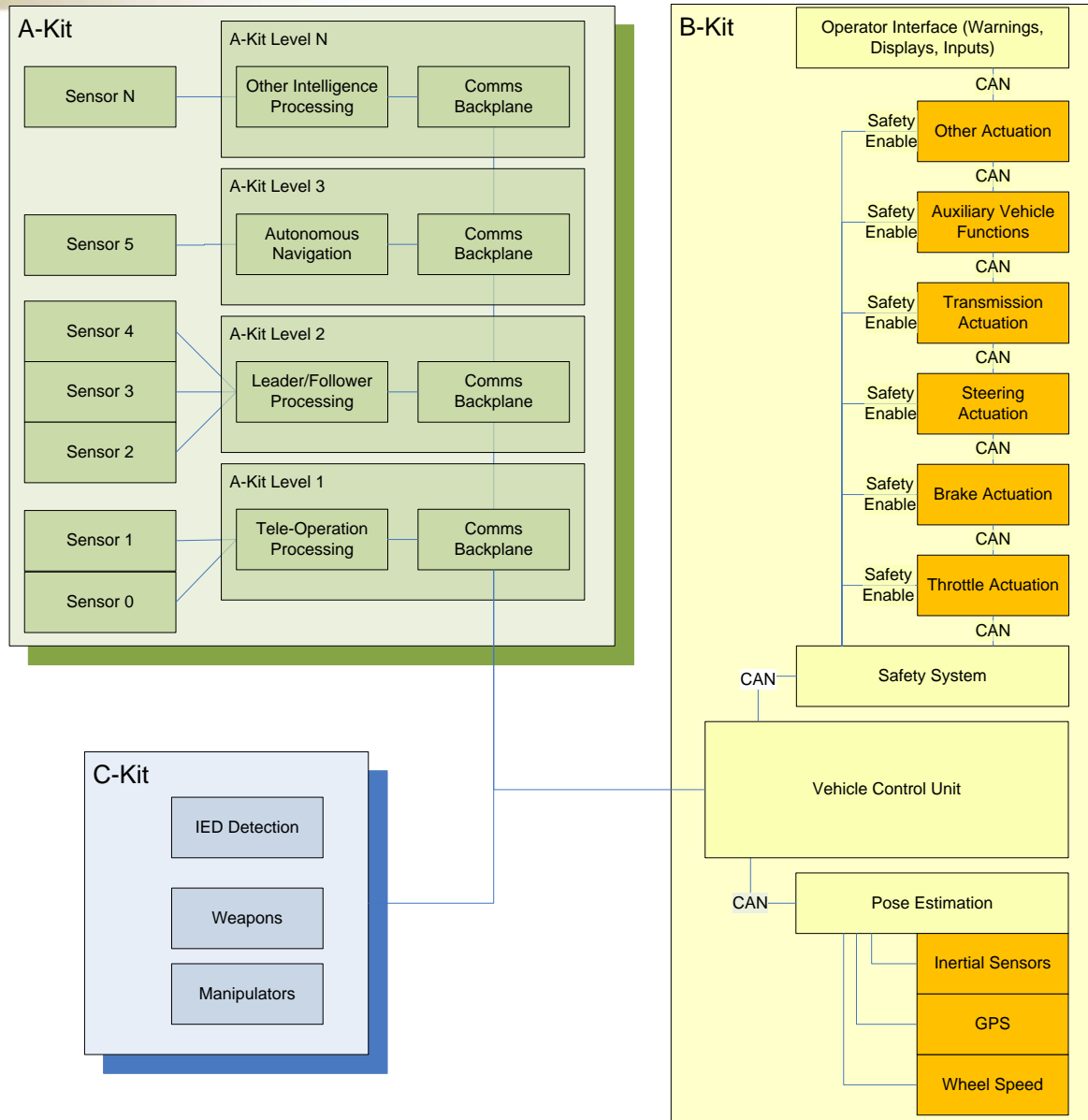
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- Provide scalable autonomy in a single material solution agnostic of platform.
  - Autonomy (A) Kit
    - » Autonomous Hardware and Sensors
  - By-wire (B) Kit
    - » Vehicle Specific Devices to Retrofit Current Tactical Vehicles
  - Common Interfaces
  - Common Framework
- Scalable and flexible to address multiple task such as convoys, security, reconnaissance, sustainment, maneuver, maneuver support.
- Utilize Existing Manned Fleet of Vehicles
  - Mobility
    - » Years of Automotive Experience
  - Leverage Mature and Developed Logistic Support
    - » Training
    - » Maintenance
    - » Spare Support
    - » ARFORGEN Cycle

- Shorten robotic platform/ function development time
- Enable scalable autonomous feature/function capabilities
- Reduce module cost and investment at an enterprise level
  - Develop a set of common electrical hardware and software interface requirements for most combat and tactical vehicle platforms
  - Consistent HW/SW interfaces and serial data implementations
  - Develop/acquire common Autonomy and Sensing Kit designs to reduce engineering, verification/ validation, and sustainment resources required.
  - At a minimum, common functionality and interfaces are required. What's "inside the Black Box" can be vendor specific.



# Example of Notional “Kit”- based System



Bundle	A-Kit	B-Kit
Safety Warning Package	Safety Sensor Kit (Radar + Camera)	none
Active Safety Package	Safety Sensor Kit	Driving Actuation Kit
Tele-op Package	Tele-op Kit (Radio + Camera)	Driving Actuation Kit
Semi-Auto Package (CAST type)	Safety Sensor Kit + Tele-op Kit	Driving Actuation Kit
Autonomous Package	Safety Sensor Kit + Tele-op Kit + Autonomous Kit (ANS Lidar)	Driving Actuation Kit

- Meets Congressional & Defense Goal for Robotic Vehicles
- Increases Warfighter Capabilities
  - Enables more capable and less costly systems
- Increases Soldier and Civilian Safety
  - Provides state-of-the art active safety functions to legacy platforms
- Shorten robotic platform/ function development time
  - Quickens deployment of new, high value systems
  - RAMP, SOURCE, CAST, and other vehicle –based robotic systems.



- Determine Robotic Feature Levels & Kit Partitioning\*
  - How many levels of A-Kit required? 3-4-5?
  - How many B-Kits needed? One per unique platform?
  - C-Kits have the most variation, but must maintain interface consistency.
- Determine potential XBW conversion alternatives
  - Deep dive existing Platforms: LTV, Stryker, MTVR, 915, etc.
- Determine Sensing and Computing alternatives
  - Perform SWAP-C & Performance analysis for system/subsystems/components
- Develop prioritized, achievable rollout plan
  - Develop program plans to implement kit development

Market Survey (RFI) for A&B Kits will be sent out to traditional DoD OEMs as well as to Automotive Suppliers – push for increased COTS at lower costs.

\* Study intended to be presented in August 2011 at GVSETS Conference

- “Massive” Kit level reuse
  - A-Kit economies of scale reduce cost and investment at the enterprise level
  - B-Kit systems remain somewhat platform dependent, but there may be common components across applications
- Deeper engagement by concentrating resources currently scattered across multiple approaches
- Shared lessons learned and best practices
  - Beginnings of a subsystem focus & SME growth
  - Document learning into functional requirements
- Commonization of similar features & functions across multiple applications
  - Basic functions used as building blocks for new capabilities
  - Faster, more reliable, & less expensive capability development and deployment

## Congressional language was a goal not a mandate

**“SEC. 220. UNMANNED ADVANCED CAPABILITY COMBAT AIRCRAFT AND GROUND COMBAT VEHICLES.**

**(a) Goal.--It shall be a goal of the Armed Forces to achieve the fielding of unmanned, remotely controlled technology such that**

**(1) by 2010, one-third of the aircraft in the operational deep strike force aircraft fleet are unmanned; and**

**(2) by 2015, one-third of the operational ground combat vehicles are unmanned.”**

- Depots
  - Many current / legacy vehicles under-utilized
  - Multi-service PMs
- LSI's
  - Building Systems to Specific Platforms
  - Repeating Work Across Platforms
  - Working Outside Expertise
    - Sensor + software + actuation
    - Sub-contracting (cost increase)
- Tier II Venders
  - Do not have specific metrics to build COTS products to



- Employ appliqué based systems, broken down into functional, inter-operable kits:
    - A – Kit: Sensor, Autonomy Software, and Communications Package
    - B – Kit: Platform Actuation Package
- } Standardized Inputs & Outputs
- Allows one-time development of a platform-specific B-Kit
    - A-Kit developers build outputs to this interface
    - Allows easier ORD modification with PM offices
  - Allows vendors to focus on their specific expertise
  - Allows platform-agnostic A-Kits and
  - Would promote vendor competition and drive down costs



- Source select multiple LSI's (2 minimum)
- Each LSI responsible for building a complete system (A, B & C kits)
- Kit inter-operability demonstrated by forcing a mixture of vendor kits on various platforms

Inter-Operable Convoy

LSI 1



A-Kit = Vender (1)  
B-Kit = Vender (1)



A-Kit = Vender (1)  
B-Kit = Vender (2)



A-Kit = Vender (2)  
B-Kit = Vender (2)

LSI 2

A-Kit = Vender (2)  
B-Kit = Vender (2)



A-Kit = Vender (2)  
B-Kit = Vender (1)



A-Kit = Vender (1)  
B-Kit = Vender (1)



Inter-Operable Convoy

- Integration and interoperability with existing systems
  - AMAS Technology design is kit-based / emphasis on COTS hardware
  - Minimize impact to legacy interfaces
    - Redundant communications for functionality in jamming environments
    - Dual kit interface path: Simple Hardware Unit / Graphical user Interface
- Functionality within operational architecture
  - Enhancement to current CONOPS
  - New functionality for legacy operation
  - Maintenance procedure development / System Training Plan (STRAP)
- Seek compliance with COCOM / XM / Sponsor guidance
  - Interoperability validation
  - Operational approval



# Top Level Capabilities & Metrics



Capability	Tasks	Metric	Baseline	Goal
FOC 09-08 Soldier Support	Operator Interventions	hours	1 per 50 hours	1 per 100 hours
Joint Land Ops	System Operation Range	Distance in meters	60 meters	100 meters
FOC 09-04 Operational Tempo	Speed	Kph	40kph	80kph
Joint Land Ops	Lateral Accuracy	centimeters from lead path	120cm	80cm
Battle space Awareness	Obstacle Avoidance	Size in cm <sup>3</sup>	1000cm <sup>3</sup>	500cm <sup>3</sup>
FOC 07-01 Protect personnel	Situational Awareness	Sighting increase %	Target sighting increase 10%	Target sighting increase 20%
FOC 07-01 Protect personnel	Emergency breaking	Interventions per hour	1	0
	Emergency breaking	Collisions	0	0
Tactical behaviors	Multi-vehicle capability	Vehicles	4	20
Collaborative Operations	Leader / follower swap	Transition time in seconds	Less than 30 seconds	Less than 10 seconds
FOC 09-04 Commonality	Platform independent hardware	% of total hardware cost	70%	85%
FOC 09-01 sustainability	Kit cost	% vehicle cost	25%	15%



- **FY11: Planning and Coordination for**
  - **Technical Assessments**
    - Interface
    - Compatibility
  - **Operational Assessments**
    - Exercises/Deployments
    - Sustainment
- **FY12:**
  - **2<sup>nd</sup> TD and OUA #1**
  - **1<sup>st</sup> OUA Report**
- **FY13:**
  - **OUA #2**
  - **Final Report / JCTD Completion**
  - **Begin CPD**
  - **Submit POM funding**

## Expected Interim Capability

- Achieved and supports EU
- Supports transition (PoR TBD)
- Fitted to vehicle
  - Stay Behind, or
  - Return to Tech Base

- **FY11-12**
  - **FY11 : draft CDD, JCTD socialization**
  - **FY12: tech demo, 1<sup>st</sup> OUA / Finalize CDD approval**
- **FY13**
  - **2<sup>nd</sup> OUA**
  - **JCTD can transition to RS-JPO**
- **FY14-16**
  - **POM Line Establishment against AMAS CDD**
  - **Confirmation of platform customers (cut-in dates and quantities)**
- **AMAS JCTD would act as near-term CDD risk reduction**
  - **Could help solidify CDD resourcing**
  - **Acts as pilot Inter-operability program**
- **AMAS focuses on inter-operability and thus is platform agnostic**
  - **A JCTD of this type should not interfere with existing platform-specific programs**
  - **I.E. MM-UGV / ARV-L**

# INTEROPERABILITY

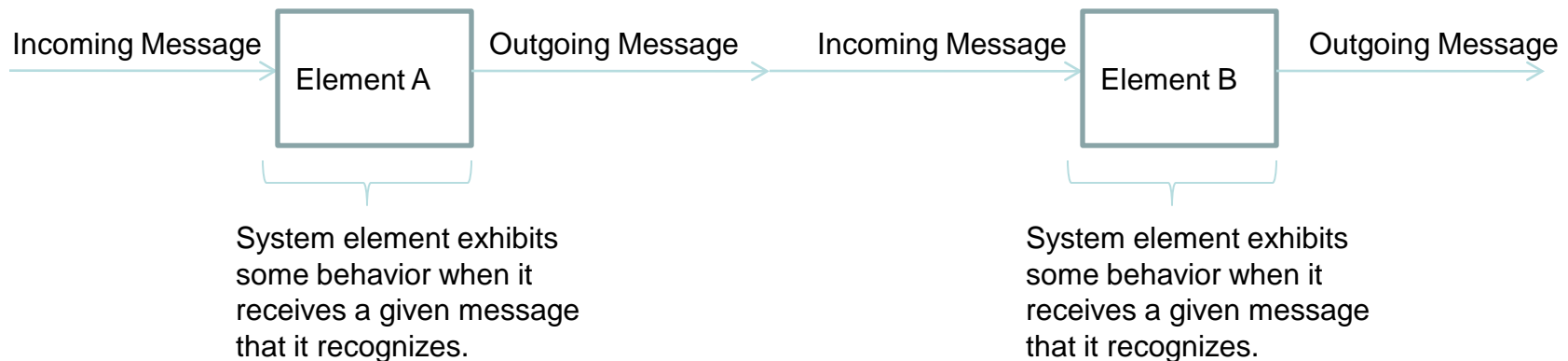


The ability of software or hardware systems or components to operate together successfully with minimal effort by end user. Further attributed with functional, behavioral, lifecycle, and architectural scopes, and, therefore, can be delineated in terms of control and can be categorized into levels, types, or degrees in application programs. Facilitated by common or standard interfaces.

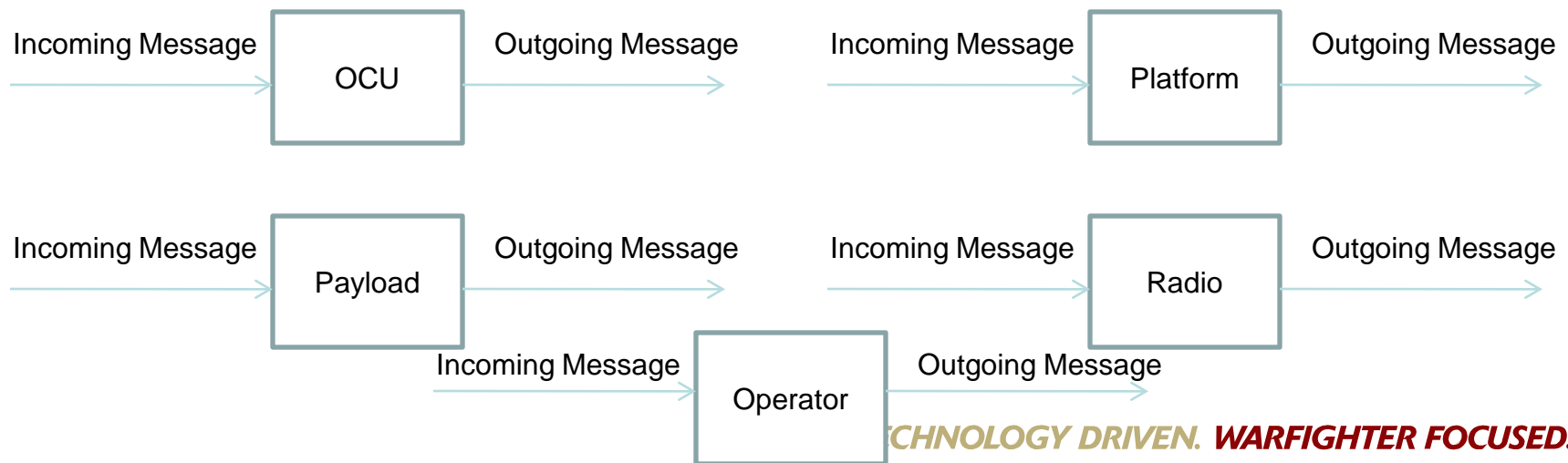
- To provide sustainable and repeatable processes and capabilities to support the current and future Warfighter
- Leverage technologies and capabilities across all UGS partner organizations
- Increased Modular payloads across multiple platforms
- Enables agile, responsive mission realignment
- Enables Air/Ground coordination/collaboration
- Broadens payload/mission equipment package vendor base
- Specifies logical architecture, standards, requirements, and conformance approach
- Offers increased capabilities at lower life cycle costs
- Facilitates common control of multiple robotic systems
- Employed by robotic Program Managers
  - Acquisition of future ground robotics system programs of record
  - Upgrade of currently fielded systems

“Interoperability is the countermeasure to obsolescence” – LTC Hatfield, ARCIC

- If common messages are used by both the sender and receiver of information, then interoperability can be achieved.
- Each element of a system knows what messages to expect.
- Each element of a system knows what messages to send.



- We need to specify what the messages are.
- Messages themselves become the interfaces.
- System / subsystem developers know which messages to expect coming in.
- System / subsystem developers know which messages need to be sent by their elements.
- Processes & algorithms within the “black boxes” use the messages & remain proprietary and invisible to others







# Interoperability Capabilities Implementation Thought Process (cont.)



- Additional things need to be defined to 1) facilitate proper delivery of messages and 2) enable modularity:
  - Physical interfaces (enabling modularity, as well as adequate throughput of messages & power for messages to flow)
  - Information handling techniques & protocols (enabling reliability of message delivery, flow control, message routing, etc.)
  - Human understandable messages for interaction between the operator and the OCU





# Interoperability Overview – Scope & Objectives



- Define interoperability standards for integration across UGVs leveraging other standards work to the greatest extent possible
  - Open Architecture & Interfaces
  - Common Control Standards
  - Communications Data Links
  - Modular Payload Interfaces
  - Conformance & Validation Criteria
- Interoperability Profile Version 0 (IOP V0) will define baseline capabilities
  - Fundamental system capabilities and functionality of fielded systems
  - Standard message sets for common control across platforms and OEM unique software coding

**Tech Base and User Communities of Interest are Embedded**

- Industry Forum – 15 June 2010

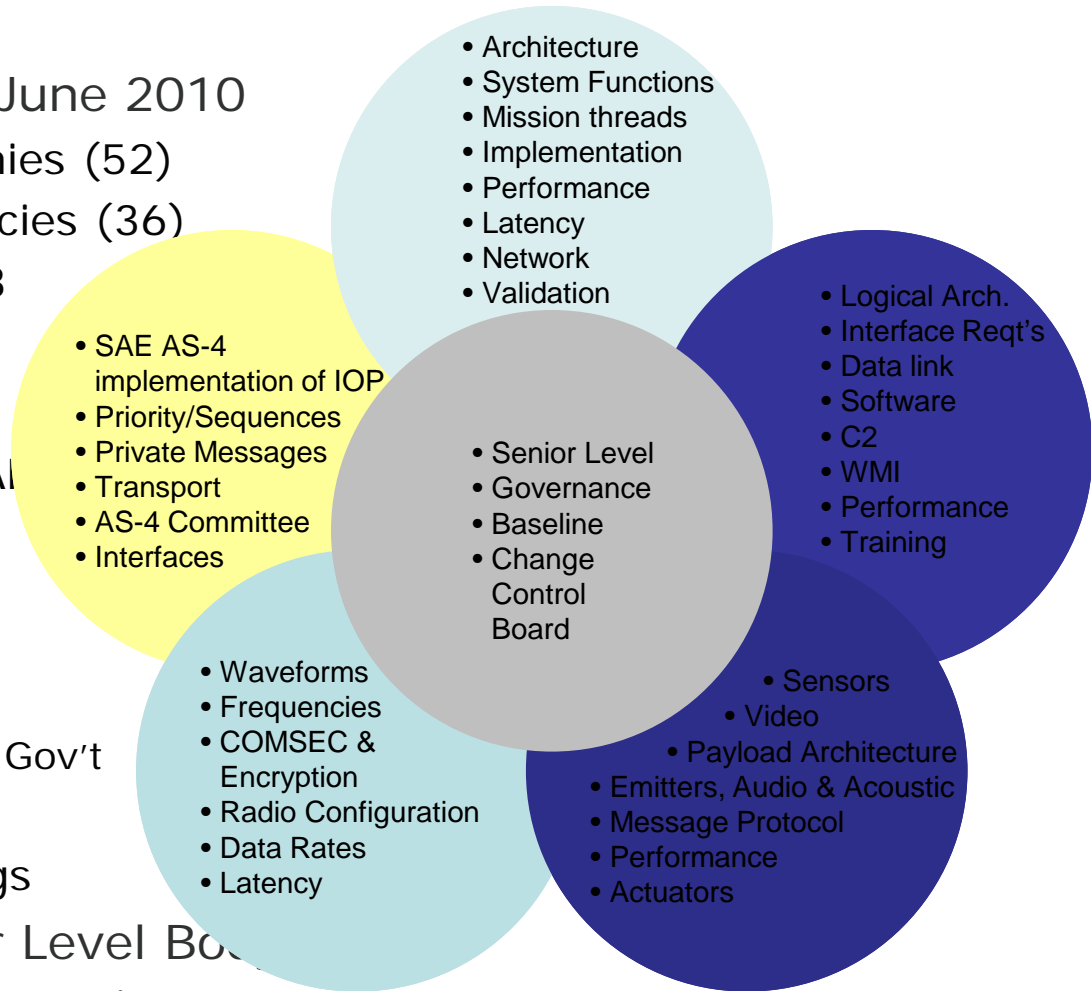
- Industry: 33 Companies (52)
- Gov't: 13 Gov't Agencies (36)
- Total Participants: 88

- Working IPT Structure

- 5 WIPTs
- Led by RSJPO and TARDEC
- Aligned with IOP Framework
- Industry and Gov't Participation
  - 15+ Companies/11 Gov't
- Rules and process
- Collaborative Meetings

- IPT Meetings (Higher Level Board)

- Cross Leveling of Information
- Baseline and Change Control





## Common Within

## Common Across

Mission Specific Payload

Power Supply

Actuator

Navigational Sensors

Mobility Platform

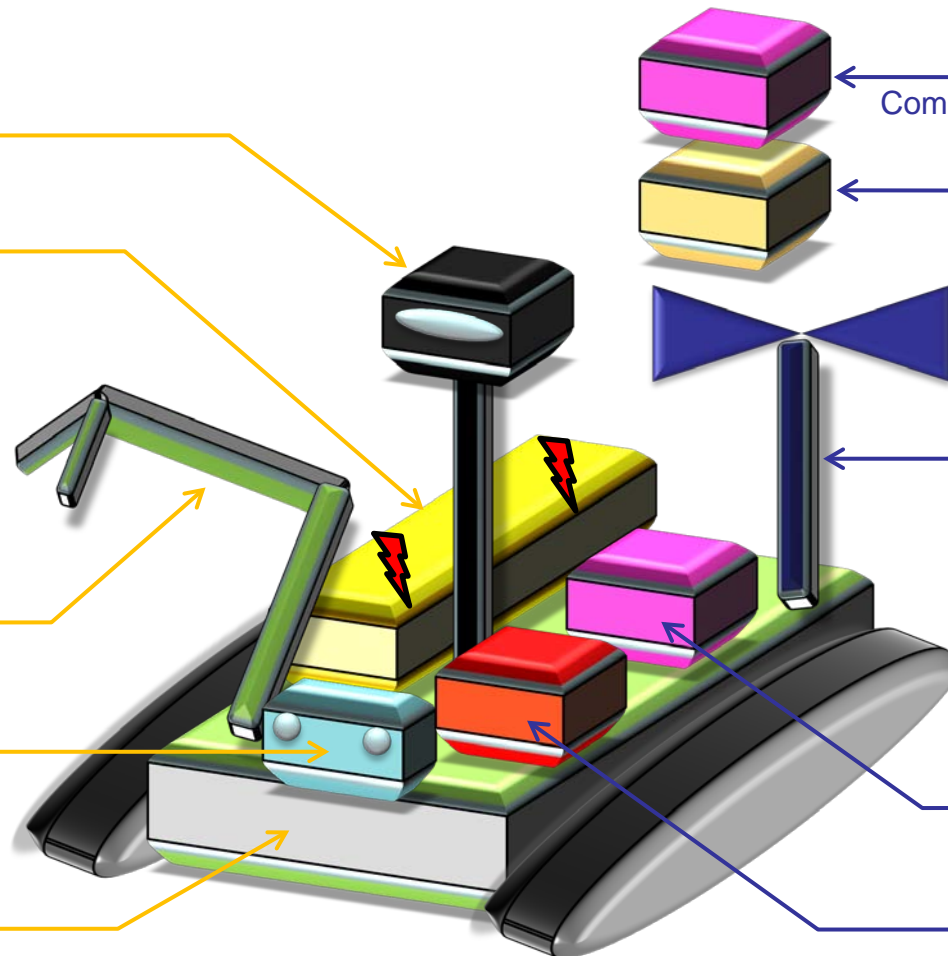
Common Integrating Software

Common Controller

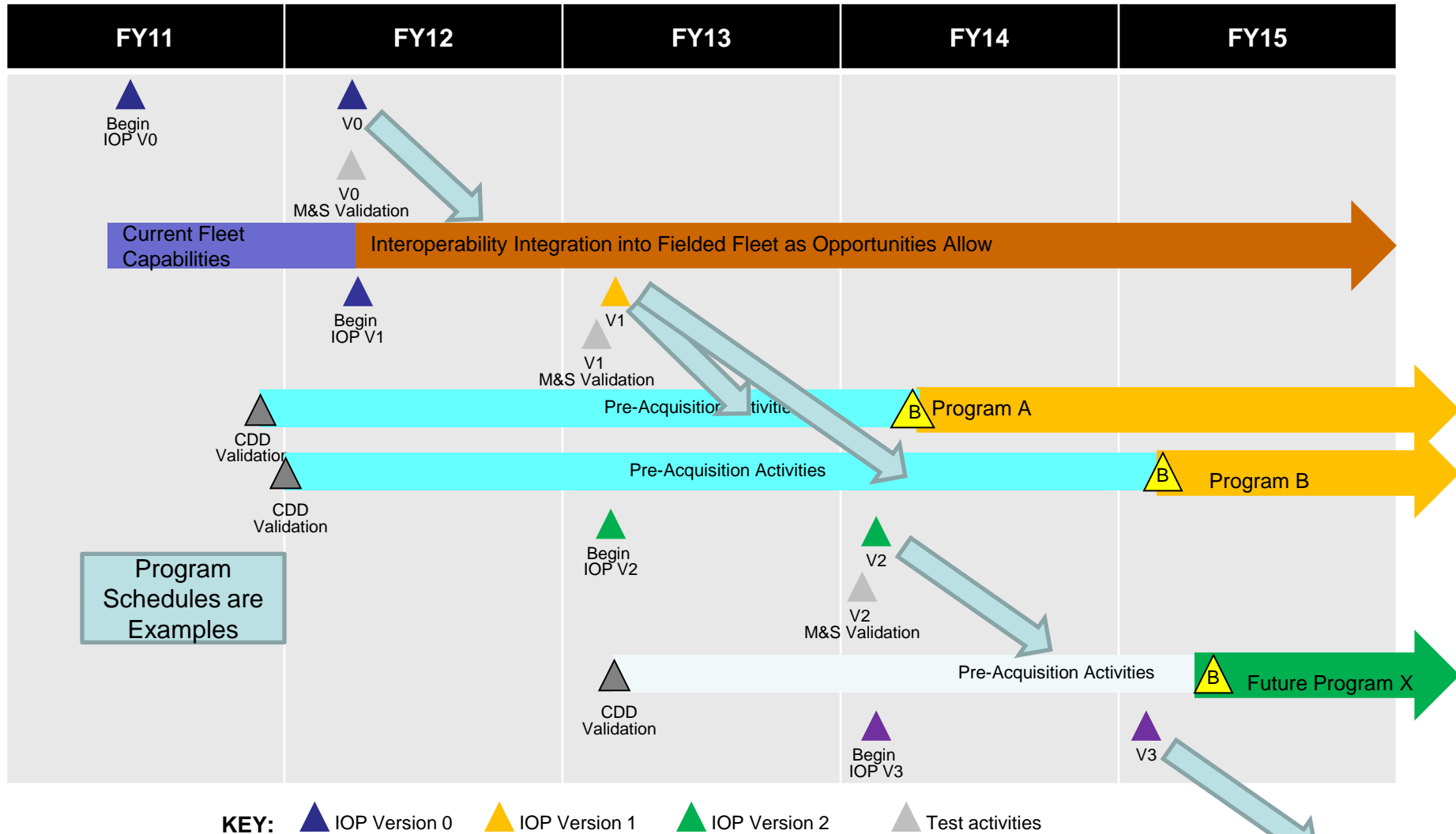
Communications

Operating Software

Artificial Intelligence



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**



- 16-17 Nov 2010 – Government / Industry WIPT Kick-Off
- Jan-Feb 2011 – Development of draft IOP V0 Capability Plan
- Feb 2011 – Establishment of WIPT Working Groups
- 09 Feb 2011 – Interoperability Synch with Navy/AEODRS
- 15 Feb 2011 – JAUS Profiling WIPT Meeting
- 03 Mar 2011 – Communications WIPT Meeting
- 10 Mar 2011 – Payloads WIPT Meeting
- 30 Mar 2011 – Overarching WIPT Meeting
- 07 April 2011 – Control WIPT Meeting

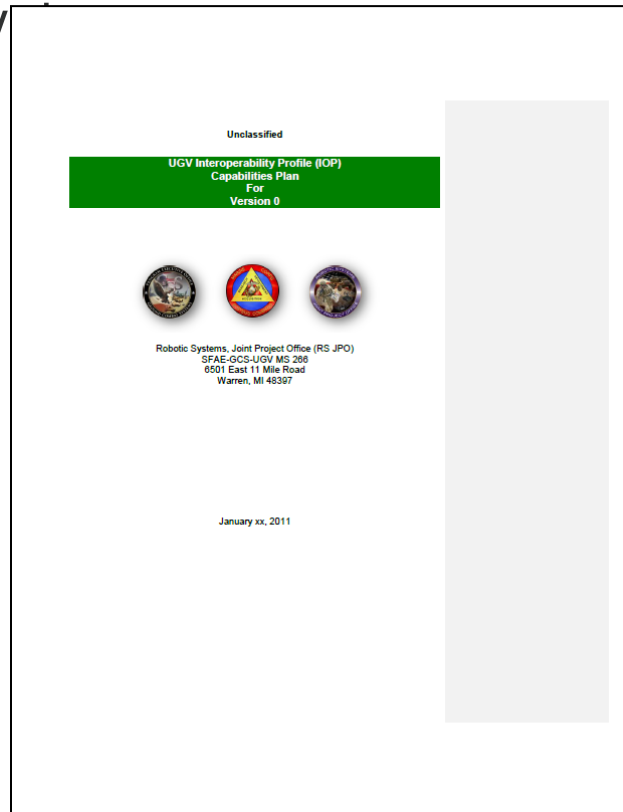


# Established Working Groups in WIPTs



WIPT	Working Groups		
Overarching	<ul style="list-style-type: none"><li>• Test &amp; Validation</li><li>• Sys Eng &amp; Architecture (TBD)</li><li>• Latency (TBD)</li></ul>		
Communications	<ul style="list-style-type: none"><li>• Radio Link</li><li>• Physical/Power Interface</li><li>• Logical Interface</li></ul>	<ul style="list-style-type: none"><li>• RFI Mitigation</li><li>• Security</li></ul>	• Radio Status Messages
J AUS Profiling	<ul style="list-style-type: none"><li>• Platform Manager</li><li>• Capability Plan Compliance</li><li>• ID Assignment</li><li>• Autonomy/Behaviors</li><li>• Access Control</li></ul>	<ul style="list-style-type: none"><li>• Digital Video Stream</li><li>• Sensors Message Implementation</li></ul>	
Payloads	<ul style="list-style-type: none"><li>• Existing Standards</li><li>• Logical Interface / Metadata</li><li>• Physical Interface</li><li>• Configuration / Taxonomy</li></ul>		
Control	<ul style="list-style-type: none"><li>• Discovery</li><li>• OCU</li><li>• Human / Machine Interface</li></ul>	<ul style="list-style-type: none"><li>• Existing Standards</li></ul>	

- V0 Capability Plan has been drafted
- Scopes & bounds what IOP V0 will define
- Focused on foundational capabilities inherent in currently fielded systems





- 3.1 Platform/Vehicle
  - Electrical, Mechanical, & Power
  - Basic Platform
    - Battery Status, Usage & Engine Data
    - Platform Mode
    - Position / Attitude
    - Sub-System Configuration & Health
    - Pose / Articulation
    - E-Stop & Heartbeat (Liveness)

- 3.1 Platform/Vehicle
  - Mobility (Basic)
    - Drive Mode
    - Gear
    - Speed / Acceleration
    - Speed / Acceleration Limits
    - Steering
    - Brake

- 3.1 Platform/Vehicle
  - Mobility (Advanced)
    - Drive Sensor Registration & Selection
    - Drive Timeout
    - Create/Insert/Delete Waypoint / Waypoint List
    - Load & Execute Waypoint Plan
    - Waypoint Following Status
    - Suspend/Resume Waypoint Following
    - Leader/Follower Mode & Attributes
    - Execute Leader/Follower Operation
    - Following Status
    - Suspend/Resume Waypoint Leader/Follower

- 3.2 Payload
  - Sensor
    - Drive Vision
    - Motion Imagery
    - Still Imagery
    - CBRN
    - Chemical Explosive Detection
    - Microphone
    - Range Finder
    - Thermal

- 3.2 Payload
  - Emitter
    - Lights
    - Speaker
  - Actuator
    - General Actuators
    - Basic Arm
    - Telescoping (Mast)
    - Pan/Tilt
    - End Affectors



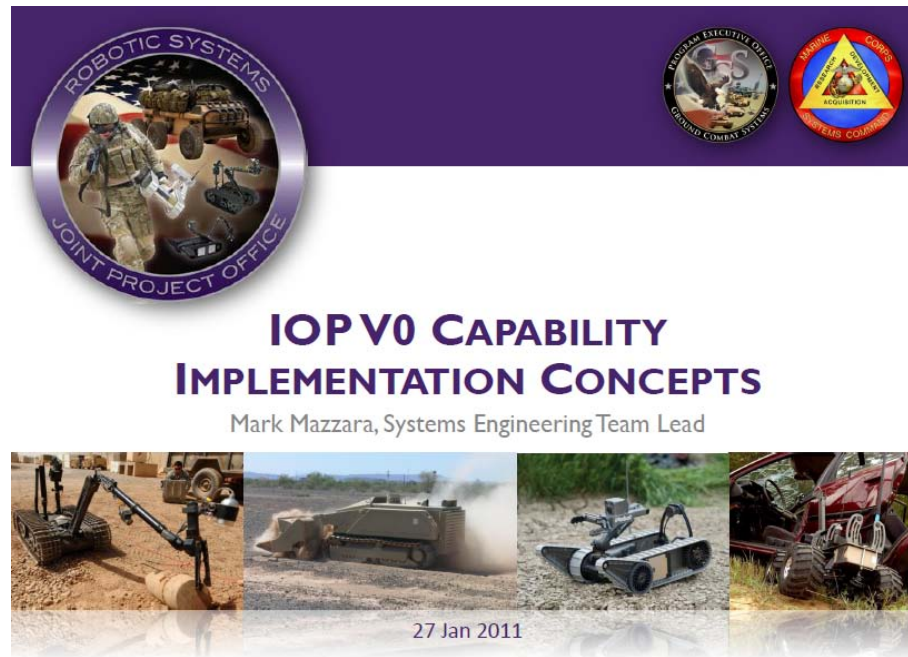
# IOP V0 Capability Plan Content (cont.)



- 3.3 Communications
  - Radio Link
  - Radio Subsystem Interface
  - Radio Frequency Interference (RFI) Mitigation
  - Radio Status Health
  - Wireless Security

- 3.4 Control
  - Human Controller Interface (HCI)
    - Battery Status Display Interface
    - Radio Setup and Comms Link Monitoring
    - Robotic Asset Selection, Login & Controls
    - Common Icons & Graphics
    - Basic Status Display
    - Warnings, Cautions & Alerts
    - State and Mode Selection
    - Input Device Mapping
    - Video Window
    - Image/Video Archive & Browsing
  - Mission Planning
    - Mission Plan Metadata and Graphics

- Slides develop as a communication tool for what needs to be defined for IOP V0
- Includes concepts & ideas for specific “instantiations” of what V0 capabilities require in terms of messages & interfaces



**IOP V0 CAPABILITY  
IMPLEMENTATION CONCEPTS**

Mark Mazzara, Systems Engineering Team Lead

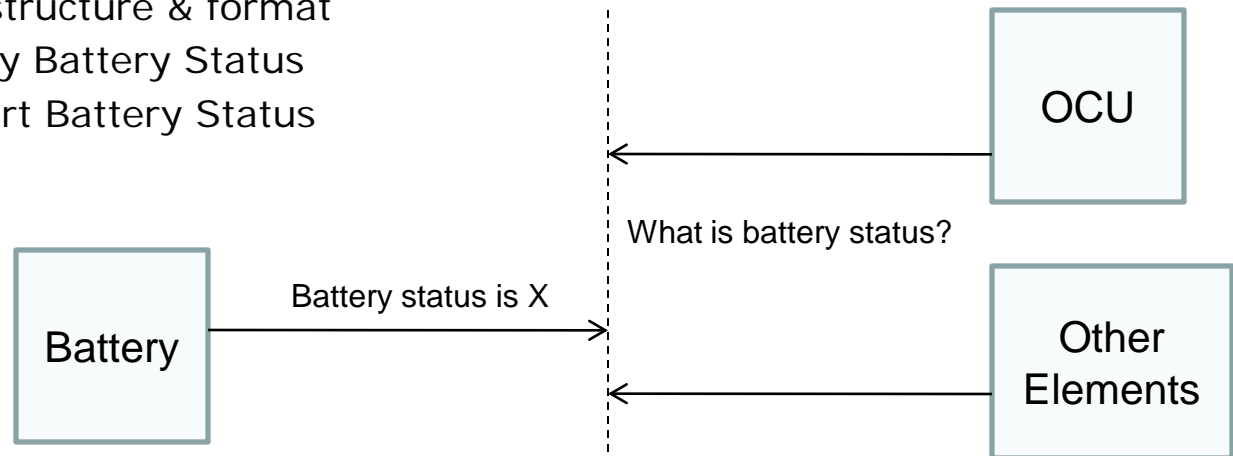
27 Jan 2011



Define Requirements: Overarching WIPT  
Define Messages: JAUS Profiling WIPT

- Battery Status:

- Description: Percentage of battery power or hours of battery operation remaining
- Action: Display a message on the OCU that provides the battery state of charge. May be a graphical display, a percentage, or a summary of expected remaining minutes of operation.
- V0 Deliverable:
  - Message structure & format
    - Query Battery Status
    - Report Battery Status



\*Conceptual Example

Open Questions:

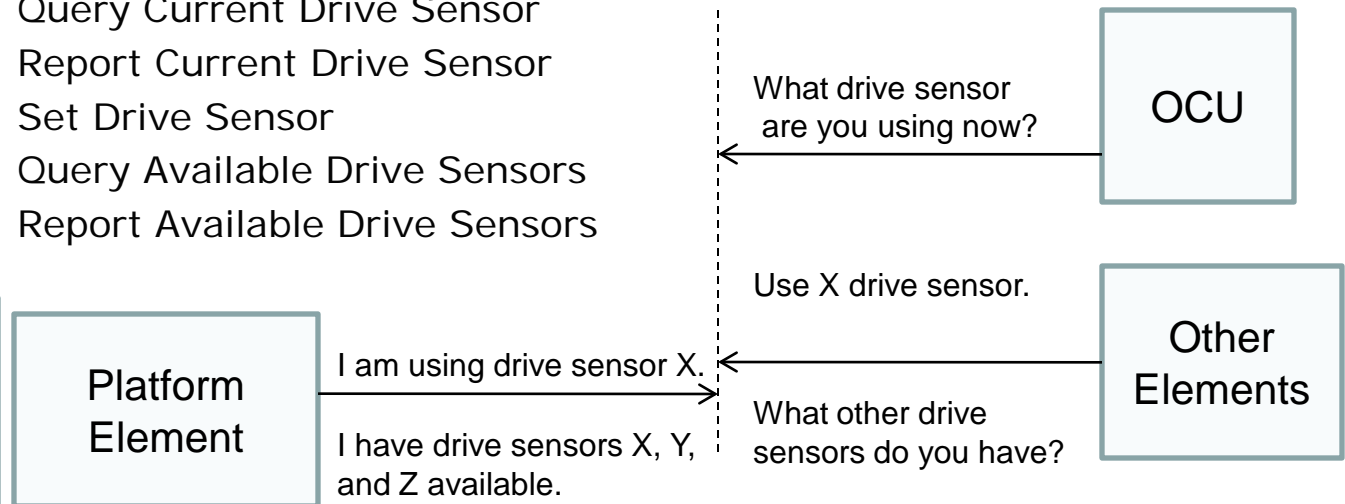
- Format as percentage?
- Format as remaining minutes?
- Define timing requirements?

Define Requirements: Payloads WIPT  
Define Messages: JAUS Profiling WIPT

- Steering:
  - Description: Specifies sensor used to drive the platform (if multiple – e.g., forward, reverse)
  - Action: Report the available drive sensors. Report current drive sensor. Set drive sensors.
  - V0 Deliverable:
    - Message structure & format
      - Query Current Drive Sensor
      - Report Current Drive Sensor
      - Set Drive Sensor
      - Query Available Drive Sensors
      - Report Available Drive Sensors

Open Questions:

- Correlate this message to Drive Mode or other messages?
- Define logical description of drive sensors in messages?
- Define timing requirements?



\*Conceptual Example

- Wireless Security:

- Description:

- Establish a secure wireless communications link

- Action:

- Determine available encryption schema and turn on/off encryption

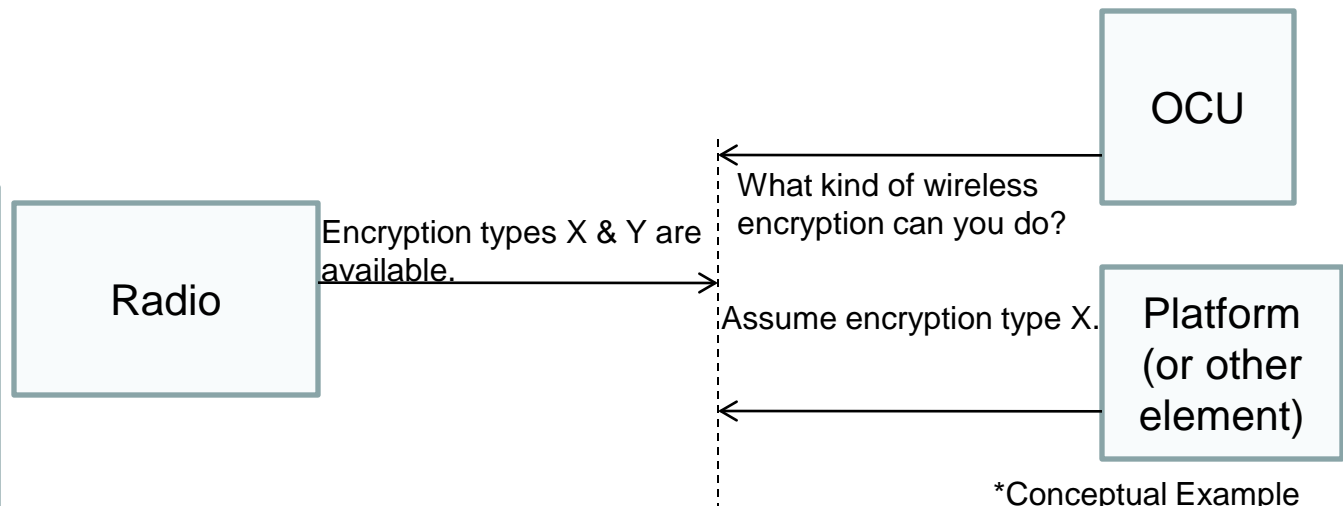
- V0 Deliverable:

- Message structure & format
  - Query/Report Available Encryption Schema
  - Set Encryption (Type X, Type Y, off, etc.)

Define Requirements: Communications WIPT  
Define Messages: JAUS Profiling WIPT

Open Questions:

- Identify minimum encryption for secure communications?
- Focus only on encryption happening within radio?
- Define timing requirements?



\*Conceptual Example



# Path Forward Toward IOP V0 Completion



- Continue regular WIPT telecons & execution of WIPT deliverables
- Develop matrix mapping V0 capabilities with existing standards messages, interfaces & protocols
  - Identify gaps in existing standards
  - Compare trades of different standards/messages that achieve similar capabilities
- Select / develop IOP V0 standards/messages with WIPTs
- Document proposed IOPs
- Staff proposed IOPs through WIPTs & JPO chain for approval
- Target September 2011 for V0 Publish



# Path Forward Toward IOP V0 Completion



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# Unmanned Ground Vehicle Interoperability

**Challenge:** Begin to address the Multi-National requirement in the Unmanned Systems Initial Capabilities Document.

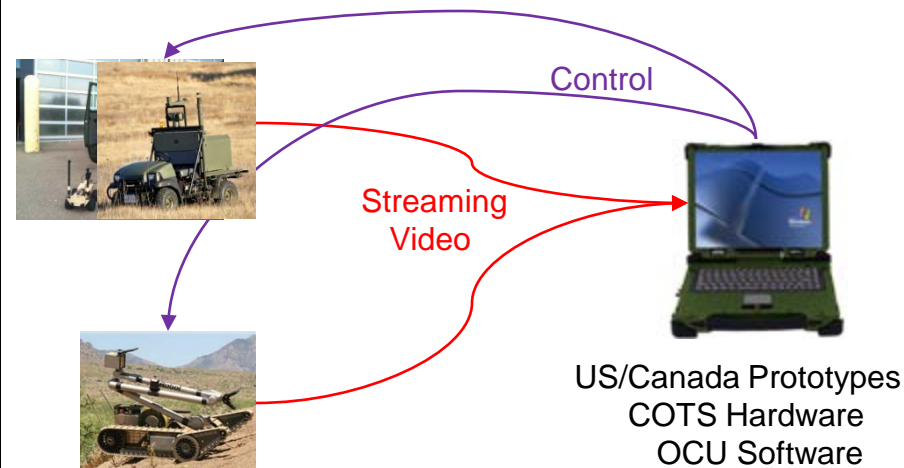
**Objective:** Use the Robotic Systems Joint Project Office (RS JPO) interoperability Profile (IOP) in a operationally relevant Coalition experiment/assessment.

**Deliverables:**

1. Software subsystems and modifications will be provided to TRADOC and/or RS JPO upon request.
2. Subject Matter Experts who worked on this program will be available for TRADOC/RS JPO if needed for further assistance.
3. Reports on the performance of OCU(s), platforms, radios and payloads to perform relevant tasks.
4. Improvements rolled into the RS JPO IOP Version 1 and 2.
5. Joint CONOPS and TTPs will be leveraged by TRADOC.

**Technology Maturity:** TRL level 7 projected at completion of CWP

**Capabilities Shortfalls Addressed:** Interoperability Profile for one Coalition partner can be used by another partner allowing for flexibility in Coalition level missions



**RS JPO Interoperability Profile V0**

Financial Information	(\$)
CWP Year One (FY12):	\$
CWP Year Two (FY13):	\$
	\$
Other US Financial Contributions:	
US Non-Financial Contributions:	\$
Foreign Financial Contributions:	\$
Foreign Non-Financial Contributions:	\$
<b>Total Project:</b>	<b>\$</b>

MILESTONE (FY)	12	13
Integrate OCU on Hardware Platform	■	
Develop software on TARDEC Robot using IOP v0	■	
Develop software on Canadian robot using IOP v0	■	
Integration and Test Both UGV		■
Relevant Demonstration (Robotics Rodeo/AEWE)		■
Final Report		▲